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RESEARCH MEMORANDUM

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FREE-FLIGHT INVESTIGATION AT TRANSONIC AND SUPERSONIC SPEEDS OF THE ROLLING EFFECTIVENESS OF A 42.7° SWEPTBACK WING HAVING PARTIAL-SPAN AILERONS

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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION AT TRANSONIC AND SUPERSONIC SPEEDS OF THE ROLLING EFFECTIVENESS OF A 42.7° SWEPTBACK WING HAVING PARTIAL-SPAN AILERONS

By Carl A. Sandahl

SUMMARY

An investigation of the rolling effectiveness at transonic and supersonic speeds of partial-span ailerons on a 42.7° sweptback wing having symmetrical circular-arc airfoil sections of 10-percent thickness ratio normal to the wing quarter-chord line has been made by means of rocket-propelled test vehicles. The results showed that with 5° aileron deflection, the rolling effectiveness decreased abruptly at about Mach number 0.90, was reversed between Mach numbers 0.94 and 1.0, and again became positive above Mach number 1.0. With 10° aileron deflection, no aileron reversal was obtained. Good agreement with regard to rolling effectiveness was obtained with data from supersonic wind-tunnel tests made at Mach number 1.9.

INTRODUCTION

In the course of an investigation of wing-aileron rolling-effectiveness characteristics at transonic and supersonic speeds being conducted by the Pilotless Aircraft Research Division of the Langley Aeronautical Laboratory utilizing rocket-propelled test vehicles in free flight, a wing-aileron configuration having a relatively large thickness ratio was tested. The wing tested was sweptback 40° at the quarter-chord line, had an aspect ratio of 4.0, a taper ratio of 0.5, and employed symmetrical circular-arc airfoil sections of 10-percent thickness ratio (NACA 2S-(50)(05)-(50)(05)) normal to the wing quarter-chord line. The ailerons were hinged at the 0.8 chord line and extended over the outboard half of the semispan. Four flight tests were made: two with the ailerons deflected 5° and two with the ailerons deflected 10°. The tests, which were made by means of the free-flight technique described in references 1 and 2, permit the evaluation of the wing-aileron rolling effectiveness over the Mach number range from about 0.6 to 1.8 at relatively large scale. The tests were made during January 1948.

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SYMBOLS

$\frac{pb}{2V}$	wing-tip helix angle, radians
C_D	drag coefficient based on total exposed wing area of 1.563 square feet
δ_a	deflection of each aileron measured in plane normal to hinge line, degrees
M	Mach number
R	Reynolds number based on average exposed wing chord of 0.55 foot
$\frac{\theta}{m}$	wing-torsional-stiffness parameter
θ	angle of twist produced by m at any section along wing span in plane parallel to model center line and normal to wing chord plane, radians
m	concentrated couple applied near wing tip in plane parallel to model center line and normal to wing chord plane, inch-pounds

TEST VEHICLES AND TESTS

The general arrangement of the test vehicles is shown in figures 1 and 2. Additional information pertinent to the test vehicles is given in table I. The wings and fuselage of the test vehicles are constructed mainly of wood. The wing-aileron configuration under investigation is attached to the rearward portion of the fuselage in a three-wing arrangement. It should be noted that unpublished tests of three and four wing configurations indicate that, with regard to rolling-effectiveness characteristics, the interference effects between the wings are negligible.

The wings are stiffened by means of steel plates cycle-welded into the upper and lower surfaces as shown in figure 1. The measured torsional-stiffness characteristics of the wings are shown in the curves of figure 3. The degree of wing torsional stiffness indicated by the curves of figure 3 has been shown by tests reported in reference 2 to be sufficient to reduce the effects of wing twisting to a negligible amount.

The test vehicles are propelled by a two-stage rocket-propulsion system to a Mach number of 1.9. During coasting flight following burnout of the rocket motor, time histories of the rolling velocity produced by the ailerons (obtained with spinsonde radio equipment) and the flight-path velocity (obtained with Doppler radar) are recorded. These data, in conjunction with atmospheric data obtained with radiosondes, permit the evaluation of the rolling-effectiveness parameter $\frac{pb}{2V}$ as a function of Mach number. The drag coefficient of the test vehicles is also obtained by a process involving the graphic differentiation of the curve of flight-path velocity against time. The scale of the tests is indicated by the curve of Reynolds number against Mach number shown in figure 4. A complete description of the techniques is given in references 1 and 2.

The accuracy of the test results is estimated to be within the following limits:

$\frac{pb}{2V}$ (due to limitations on model constructional accuracy)	±0.005
$\frac{pb}{2V}$ (due to limitations on instrumentation)	±0.0005
C_D	±0.002
M	±0.005

It will be noted, as was pointed out in reference 1, that owing to the relatively small moment of inertia about the rolling axis, the measured values of $\frac{pb}{2V}$ are substantially steady-state values even though the test vehicles are experiencing an almost continuous rolling acceleration and deceleration. Except for abrupt changes of $\frac{pb}{2V}$ with Mach number which occur in the Mach number range from about 0.9 to 1.0, the correction is estimated to be within 3 percent. Between Mach numbers of 0.9 and 1.0 the maximum correction corresponding to the maximum attained rolling acceleration of 100 radians per second squared, assuming a damping-in-roll coefficient of 0.2, is 10 percent. The data presented herein have not been corrected for inertia effects.

RESULTS AND DISCUSSION

The results of the present investigation are shown in figure 5 as curves of $\frac{pb}{2V}$ and C_D as functions of Mach number.

As shown in figure 5, the wing-aileron rolling effectiveness decreased with increasing Mach number in the Mach number range from about 0.62 to about 0.90 for both 5° and 10° aileron deflections. With 5° deflection, the effectiveness was reduced abruptly in the Mach number range from about 0.90 to 0.94 and was reversed from Mach number 0.94 to about 1.0, at which Mach number the effectiveness again became positive. With 10° deflection no reversal of aileron effectiveness was obtained.

In an effort to develop a wing-aileron configuration which would not be subject to reversal of effectiveness at transonic speeds, an extensive investigation of a semispan model of the wing used in the present tests has been conducted in the Langley high-speed 7- by 10-foot tunnel using the "bump" technique. These tests are described in reference 3. Several modifications to the original aileron configuration were developed which produced positive rolling moments for all deflections at transonic speeds. Because of the difficulty of estimating the damping-in-roll coefficient in the Mach number range of the "bump" tests, no attempt has been made to correlate the results of the present flight tests and the "bump" tests.

Also shown in figure 5 is the rolling-effectiveness parameter $\frac{pb}{2V}$ calculated from static aileron rolling-moment measurements in the Langley 9- by 12-inch supersonic blowdown tunnel of a semispan model of the wing used in the present tests. The wind-tunnel tests were made at a Mach number of 1.9 and at a Reynolds number of 2.2×10^6. In calculating $\frac{pb}{2V}$ from the wind-tunnel results a damping-in-roll coefficient of -0.31 was used. This value is from unpublished work of the stability analysis section of the Langley Laboratory utilizing methods based on the linearized supersonic-flow equations. Good agreement exists between the tunnel and the present free-flight tests.

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REFERENCES

1. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM No. L7D02, 1947.

2. Sandahl, Carl A.: Free-Flight Investigation of Control Effectiveness of Full-Span, 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Wing Sweepback, Taper, Aspect Ratio, and Section Thickness Ratio. NACA RM No. L7F30, 1947.

3. Turner, Thomas R., Lockwood, Vernard E., and Vogler, Raymond D.: Preliminary Investigation of Various Ailerons on 42° Sweptback Wings for Lateral Control at Transonic Speeds. NACA RM No. L8D21, 1948.

TABLE I

GEOMETRIC CHARACTERISTICS OF TEST VEHICLES

Total exposed wing area, sq ft	1.563
Aspect ratio	[a]4.0
Taper ratio	[a]0.5
Sweepback of wing leading edge, deg	42.7
Sweepback of wing trailing edge, deg	30.5
Ratio of aileron chord to wing chord	0.20
Ratio of aileron span to wing span	[a]0.50
Angle between upper and lower wing surfaces at trailing edge measured in plane normal to quarter-chord line, deg	22.6
Angle between upper and lower wing surfaces at trailing edge measured in plane parallel to test-vehicle center line, deg	21.7
Moment of inertia about roll axis, slug-ft^2	0.0556

[a]Obtained by extending leading edge and trailing edge to center line of test vehicle.

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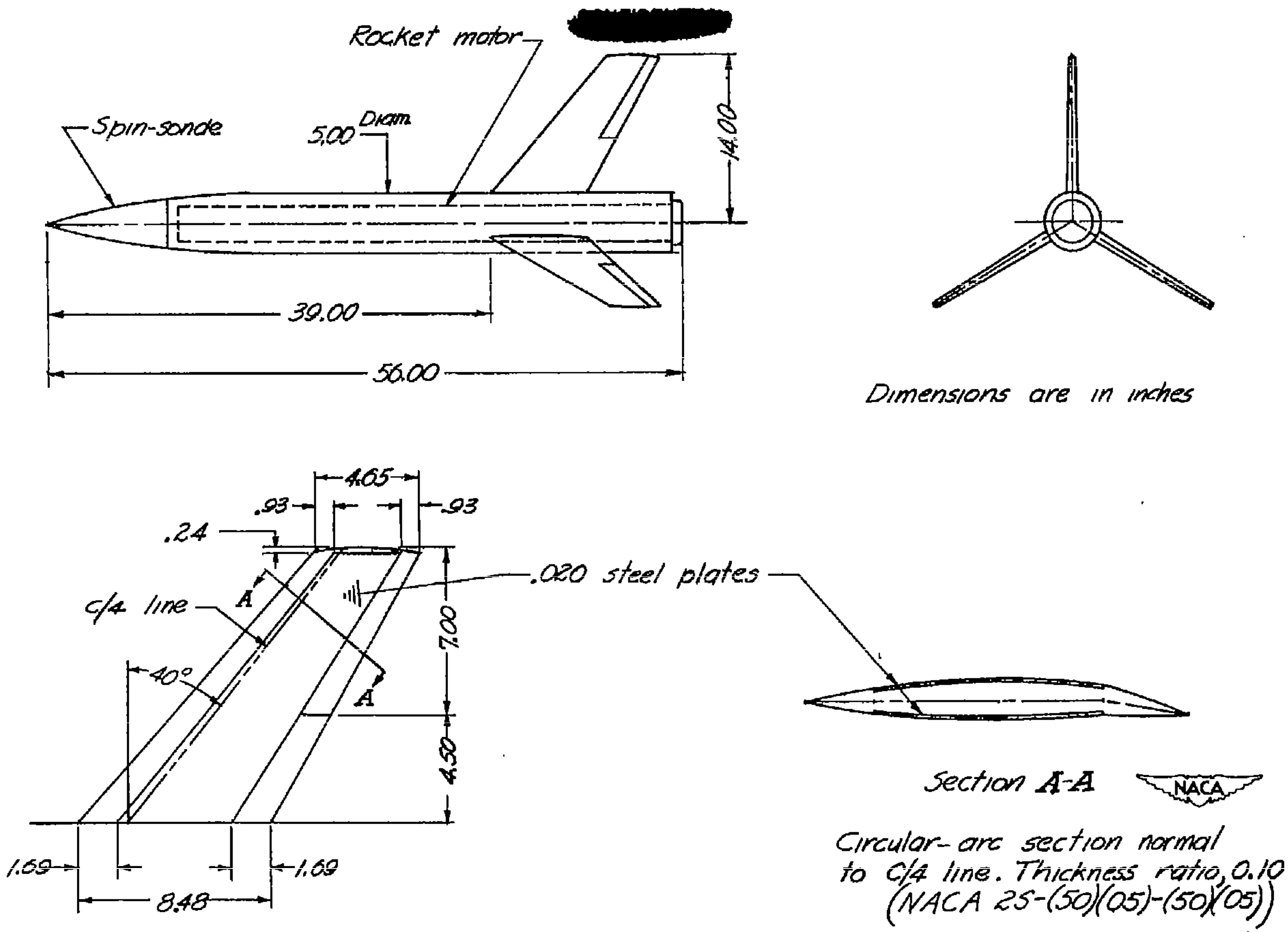

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Figure 1.- General arrangement of test vehicles.

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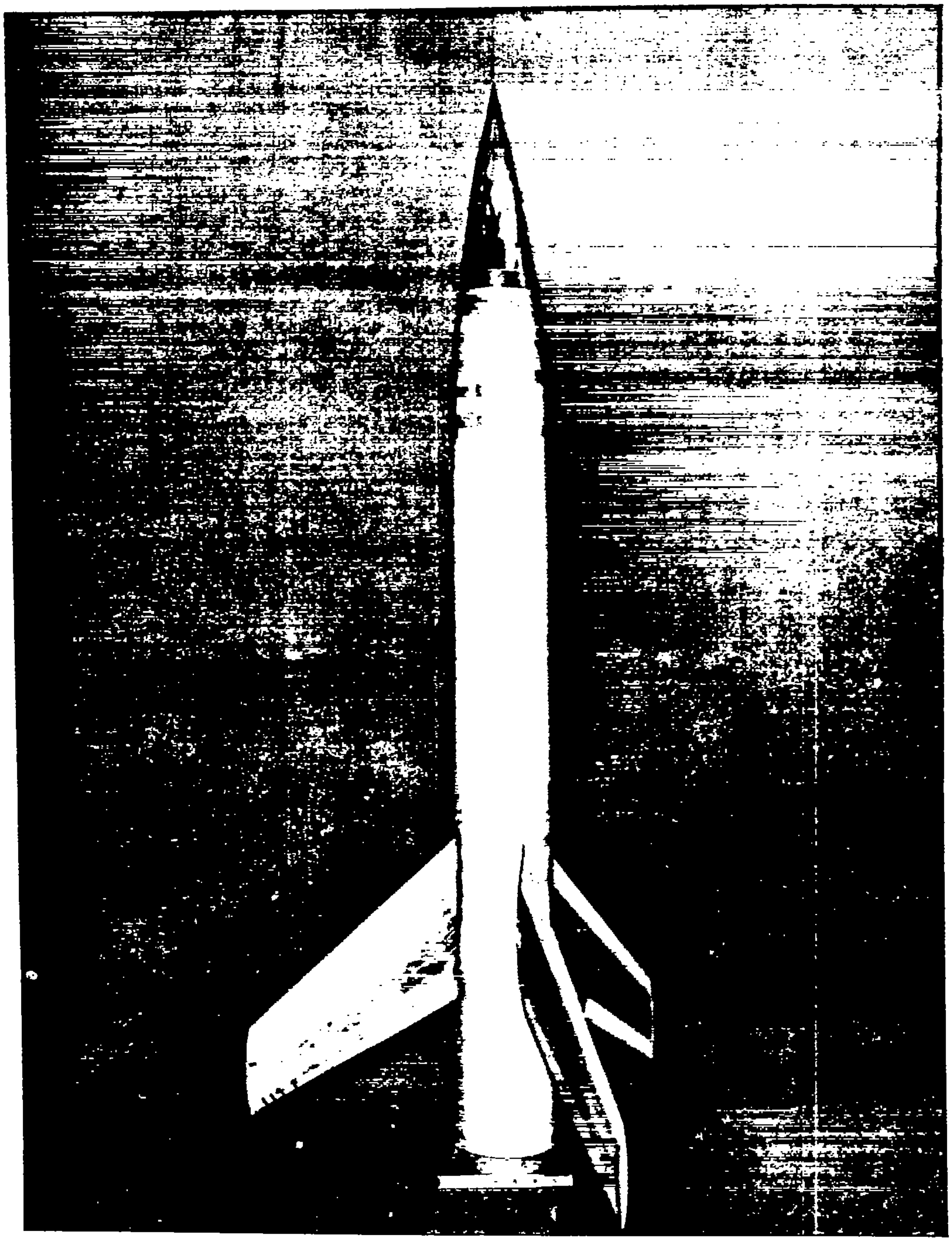

Figure 2.- Photograph of test vehicle.

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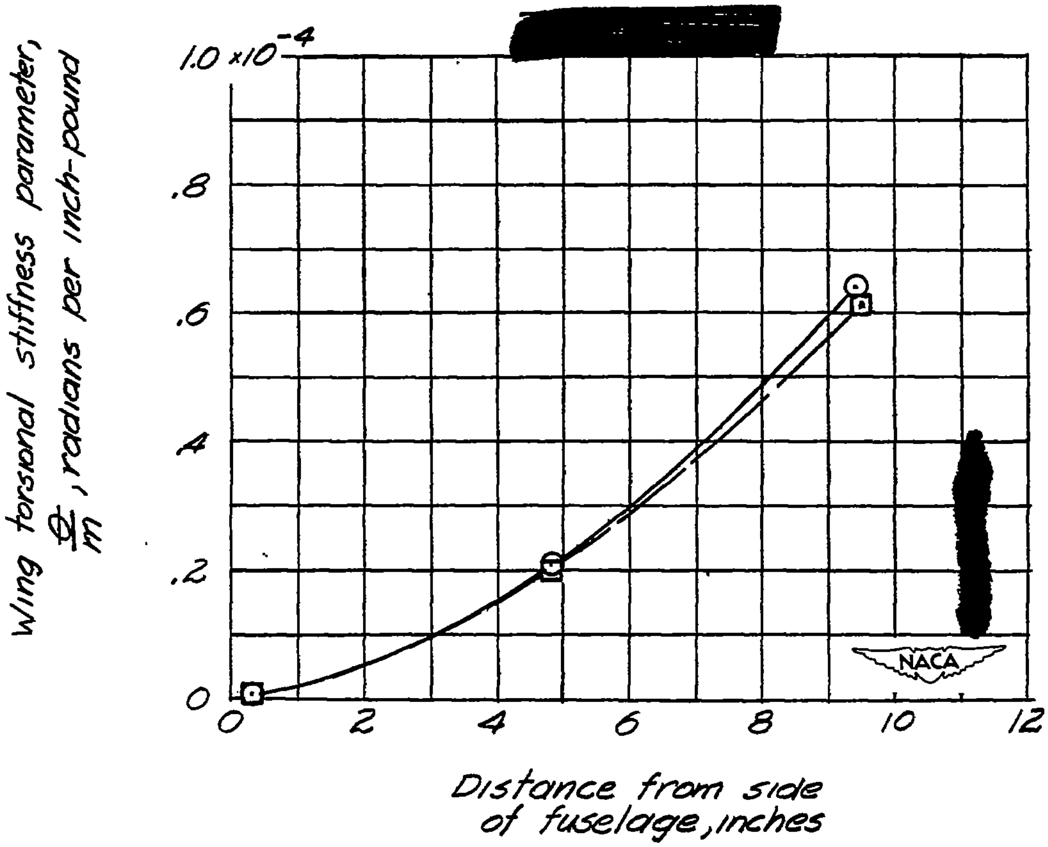

Figure 3.- Stiffness characteristics of two typical wings of the present tests.

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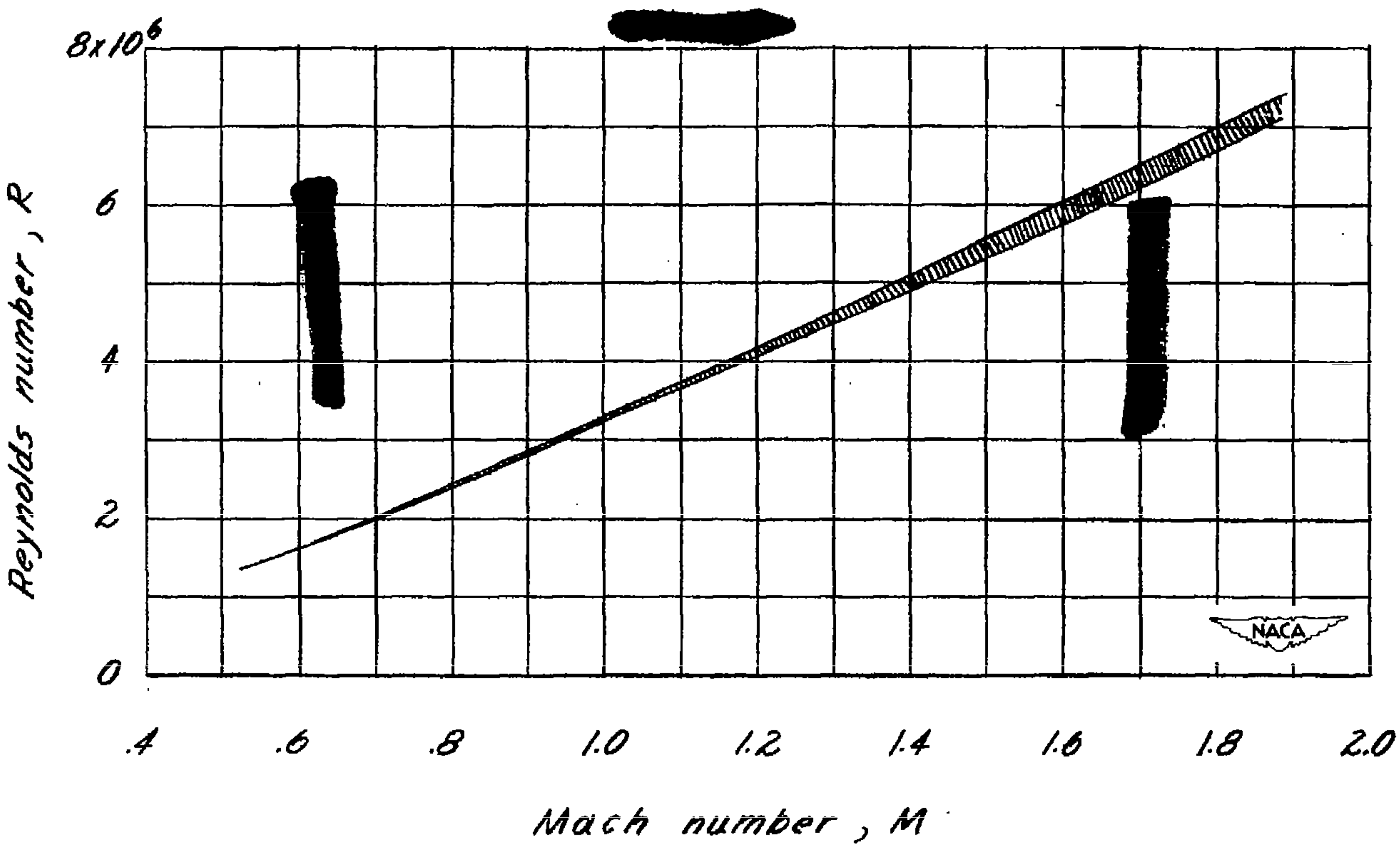

Figure 4.- Variation of Reynolds number with Mach number for test conditions. [redacted]

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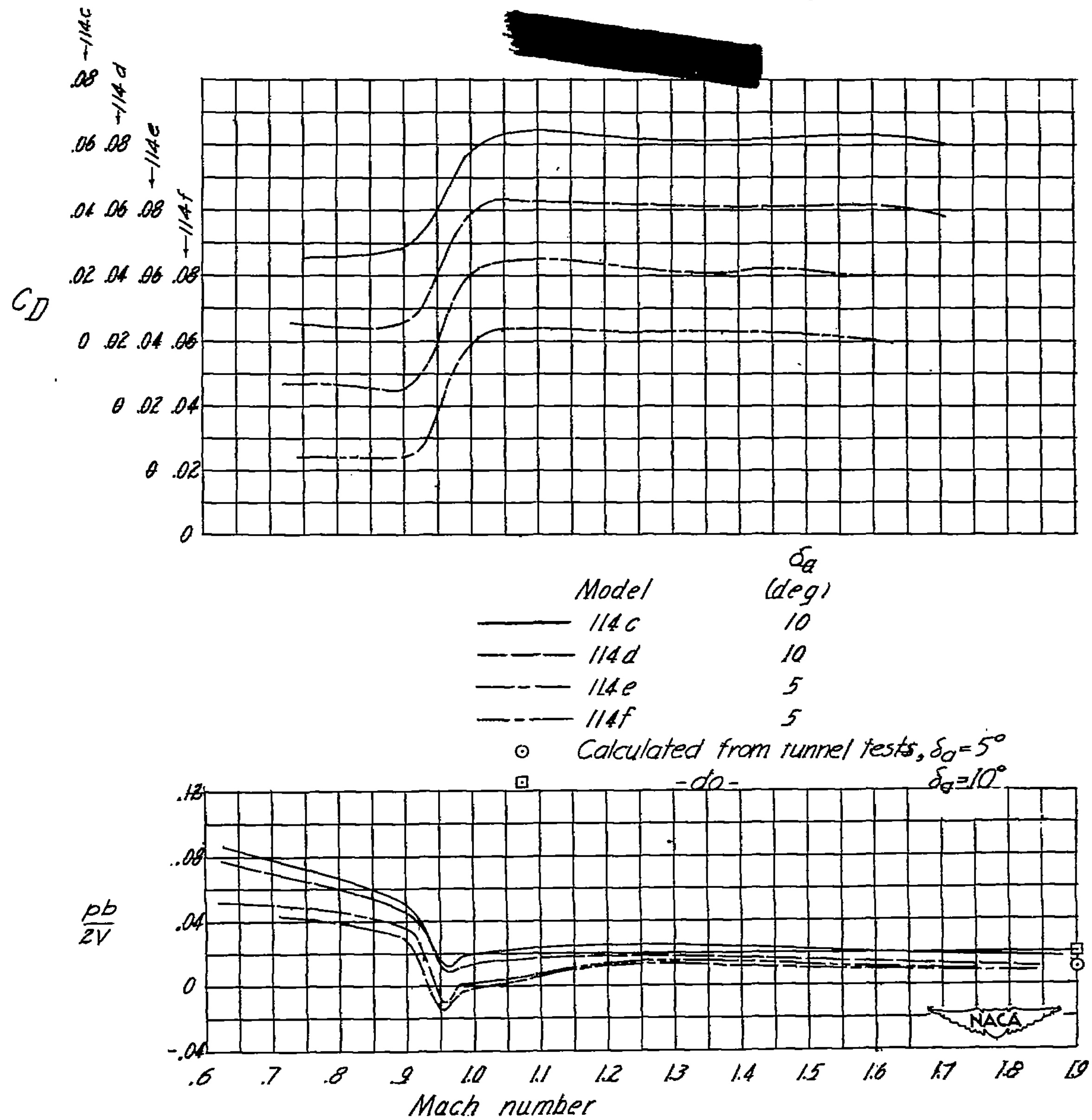

Figure 5.- Test results. [redacted]